

CLAIMS

What is claimed is:

1. A method for determining the best entry point for a percutaneous procedure,
5 given a primary target for biopsy and a secondary target through which a biopsy needle
must pass on its way to said primary target, comprising:-

selecting a first arbitrary entry point on a patient;

selecting a second arbitrary entry point on said patient, different from said first
arbitrary entry point;

10 determining the three dimensional (3-D) orientation of said needle at said first
arbitrary entry point for pointing said needle at said primary target;

determining the 3-D orientation of said needle at said first arbitrary entry point for
pointing said needle at said secondary target;

determining the 3-D dimensional orientation of said needle at said second
15 arbitrary entry point for pointing said needle at said primary target;

determining the 3-D orientation of said needle at said second arbitrary entry point
for pointing said needle at said secondary target;

determining a 3-D line representing the intersection of
a first plane containing said first arbitrary entry point, said primary target point, and said
20 secondary target point, and

a second plane containing said second arbitrary entry point, said primary target, and said
secondary target point, whereby said 3-D line provides a position and orientation for said
needle for performing needle biopsy of said primary target through said secondary target.

2. A method for use in conjunction with a C-arm imaging apparatus, for positioning a biopsy needle from a given entry point on a patient to a given target for biopsy, comprising:

positioning said C-arm in a desired first position, whereby an image formed with
5 said C-arm in said first position is formed in a first image plane;

storing location information of said given target in said first image plane;

defining a first arbitrary plane including said given entry point;

placing said needle at said given entry point;

visually servoing said needle in said first arbitrary plane with respect to said
10 location information in said first image plane to derive a first three-dimensional (3-D)
needle position;

defining a second arbitrary plane including said given entry point, different from
said first arbitrary plane;

placing said needle at said given entry point;

visually servoing said needle in said second arbitrary plane with respect to said
15 location information in said image plane to derive a second three-dimensional (3-D)
needle position;

determining a resulting plane defined by said first and second three-dimensional
(3-D) needle positions;

20 placing said needle at a selected point in said resulting plane at an arbitrary
orientation;

positioning said C-arm in a desired second position, whereby an image formed
with said C-arm in said second position is formed in a second image plane;

storing location information of said given target in said second image plane; and

visually servoing said needle around said entry point in said resulting plane with
25 respect to said location information in said second image plane, whereby said needle is at
said entry point and aimed at said target.

3. A method for use in conjunction with a C-arm imaging apparatus, for visual
servoing of a needle in a plane in a fixed number of iterations, with: a given position of
said C-arm being modeled on an image plane, a given target point for needle biopsy, a
5 given entry point on a patient, and a given plane within which said needle can rotate
around said given entry point, said method comprising:

placing said needle in an arbitrary orientation around said given entry point, said
orientation being associated with an angle θ_1 with respect to an arbitrary reference
direction;

10 obtaining a 2-dimensional (2-D) projection image of said needle in said image
plane;

measuring the position 11 of said 2-D projection image;

rotating said needle around said entry point by an angle $\Delta\theta$ to a position $(\theta_1 + \Delta\theta)$
in said given plane;

15 measuring the position 12 of said 2-D projection image;

rotating said needle around said entry point by an angle $\Delta\theta$ to a position
 $\theta_3 = (\theta_1 + 2 * \Delta\theta)$;

measuring the position 13 of said 2-D projection image;

20 locating 2-D points f and t in said 2-D projection image that are the respective 2-
D projections of said target point and said entry point, said points f and t defining an
image line $It = (ft)$;

calculating the cross-ratio $c = (11, 12, 13, It)$;

determining a 3-D angle θ_t such that $c = (\theta_1, \theta_2, \theta_3, \theta_t)$; and

25 rotating said needle around said entry point by θ_t from position θ_3 in said given
plane, whereby said needle is positioned in three dimensional space at said entry point
along a direction such that said needle is visually aligned to 2-D projection image of said
target in said image plane.

4. A method for visual servoing of a needle in a plane in a fixed number of iterations as recited in claim 3, wherein said step of locating 2-D points f and t is performed automatically.

5. A method for visual servoing of a needle in a plane in a fixed number of iterations as recited in claim 3, wherein said step of locating 2-D points f and t is performed manually.

6. Apparatus for determining the best entry point for a percutaneous procedure, given a primary target for biopsy and a secondary target through which a biopsy needle must pass on its way to said primary target, said apparatus comprising:

means for selecting a first arbitrary entry point on a patient;

means for selecting a second arbitrary entry point on said patient, different from said first arbitrary entry point;

means for determining the three dimensional (3-D) orientation of said needle at said first arbitrary entry point for pointing said needle at said primary target;

means for determining the 3-D orientation of said needle at said first arbitrary entry point for pointing said needle at said secondary target;

means for determining the 3-D dimensional orientation of said needle at said second arbitrary entry point for pointing said needle at said primary target;

means for determining the 3-D orientation of said needle at said second arbitrary entry point for pointing said needle at said secondary target;

means for determining a 3-D line representing the intersection of a first plane containing said first arbitrary entry point, said primary target point, and said secondary target point, and

a second plane containing said second arbitrary entry point, said primary target, and said secondary target point, whereby said 3-D line provides a position and orientation for said needle for performing needle biopsy of said primary target through said secondary target.

7. Apparatus for use in conjunction with a C-arm imaging apparatus, for positioning a biopsy needle from a given entry point on a patient to a given target for biopsy, said apparatus comprising:

means for positioning said C-arm in a desired first position, whereby an image formed with said C-arm in said first position is formed in a first image plane;

means for storing location information of said given target in said first image plane;

means for defining a first arbitrary plane including said given entry point;

means for placing said needle at said given entry point;

means for visually servoing said needle in said first arbitrary plane with respect to said location information in said first image plane to derive a first three-dimensional (3-D) needle position;

means for defining a second arbitrary plane including said given entry point, different from said first arbitrary plane;

means for placing said needle at said given entry point;

means for visually servoing said needle in said second arbitrary plane with respect to said location information in said image plane to derive a second three-dimensional (3-D) needle position;

means for determining a resulting plane defined by said first and second three-dimensional (3-D) needle positions;

means placing said needle at a selected point in said resulting plane at an arbitrary orientation;

means for positioning said C-arm in a desired second position, whereby an image formed with said C-arm in said second position is formed in a second image plane;

means for storing location information of said given target in said second image plane; and

means for visually servoing said needle around said entry point in said resulting plane with respect to said location information in said second image plane, whereby said needle is at said entry point and aimed at said target.

8. Apparatus for use in conjunction with a C-arm imaging apparatus, for visual servoing of a needle in a plane in a fixed number of iterations, with: a given position of said C-arm being modeled on an image plane, a given target point for needle biopsy, a given entry point on a patient, and a given plane within which said needle can rotate around said given entry point, said apparatus comprising:

means for placing said needle in an arbitrary orientation around said given entry point, said orientation being associated with an angle θ_1 with respect to an arbitrary reference direction;

means for obtaining a 2-dimensional (2-D) projection image of said needle in said image plane;

means for measuring the position 11 of said 2-D projection image;

means for rotating said needle around said entry point by an angle $\Delta\theta$ to a position $(\theta_1 + \Delta\theta)$ in said given plane;

means for measuring the position 12 of said 2-D projection image;

means for rotating said needle around said entry point by an angle $\Delta\theta$ to a position $\theta_3 = (\theta_1 + 2 \cdot \Delta\theta)$;

means for measuring the position 13 of said 2-D projection image;

means for locating 2-D points f and t in said 2-D projection image that are the respective 2-D projections of said target point and said entry point, said points f and t defining an image line $It = (ft)$;

means for calculating the cross-ratio $c = (11, 12, 13, It)$;

means for determining a 3-D angle θ_t such that $c = (\theta_1, \theta_2, \theta_3, \theta_t)$; and

means for rotating said needle around said entry point by θ_t from position θ_3 in said given plane, whereby said needle is positioned in three dimensional space at said

entry point along a direction such that said needle is visually aligned to 2-D projection image of said target in said image plane.

5 9. Apparatus for visual servoing of a needle in a plane in a fixed number of iterations as recited in claim 8, wherein said means for locating 2-D points f and t is automatic.

10. A method for visual servoing of a needle in a plane in a fixed number of iterations as recited in claim 8, wherein said means for locating 2-D points f and t allows manual operation.

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